Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
TX-99/2946-S		

4. Title and Subtitle	5. Report Date
SAFETY OF DRIVEWAYS IN CLOSE PROXIMITY TO EACH OTHER	October 1998
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Hayes E. Ross, Jr., King K. Mak, and Rajen K. Lavingia	Report 2946-S

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. Project No. 7-2946

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Research and Technology Transfer Office P. O. Box 5080 Austin, Texas 78763-5080	Project Summary: September 1996 - August 1997
	14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with the Texas Department of Transportation
Research Project Title: Evaluation of Safety End Treatments on Parallel Drainage Structures

16. Abstract

Preliminary guidelines were developed for minimum spacing of driveways on high speed roadways. The guidelines address safety concerns related to ran-off-the-road accidents. The purpose of the guidelines is to minimize the risk to an errant motorist who leaves the road, crosses a driveway/sloped end culvert, and then becomes airborne. It is desirable to have a safe recovery area downstream from the driveway—one that is free of hazardous features, including another driveway.

This study was intended to be a two-year study, with the effort in the first year concentrating on a summary of existing practices and accident experience throughout Texas and other state DOTs. Work in the second year was to fill voids in the data found in the first year's work. Very little substantive data was found through surveys of state practices and through accident data. A limited computer simulation study was conducted with the Highway-Vehicle-Object-Simulation-Model (HVOSM) to gain insight into vehicular behavior upon crossing a driveway. Use of HVOSM provided data from which preliminary spacing criteria could be developed. Funding for the second year's work was not approved, and hence more comprehensive guidelines were not developed.

17. Key Words	18. Distribution Statement
Culvert, Driveway, Highway, Roadside, Safety, Spacing	No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	58	

SAFETY OF DRIVEWAYS IN CLOSE PROXIMITY TO EACH OTHER

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Report 2946-S
Project Number 7-2946
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Parallel Drainage Structures

Sponsored by the
Texas Department of Transportation

October 1998

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IMPLEMENTATION RECOMMENDATIONS

Preliminary guidelines were developed for minimum spacing of driveways on high speed roadways. The guidelines address safety concerns related to ran-off-the-road accidents. The purpose of the guidelines is to minimize the risk to an errant motorist who leaves the road, crosses a driveway/sloped end culvert, and then becomes airborne. It is desirable to have a safe recovery area downstream from the driveway—one that is free of hazardous features, including another driveway.

This study was intended to be a two-year study, with the effort in the first year concentrating on a summary of existing practices and accident experience throughout Texas and other state DOTs. Work in the second year was to fill voids in the data found in the first year's work. Very little substantive data was found through surveys of state practices and through accident data. A limited computer simulation study was conducted with the Highway-Vehicle-Object-Simulation-Model (HVOSM) to gain insight into vehicular behavior upon crossing a driveway. Use of HVOSM provided data from which preliminary spacing criteria could be developed. Funding for the second year's work was not approved, and hence more comprehensive guidelines were not developed. Nonetheless, TxDOT may wish to implement the preliminary findings on a limited, experimental basis, subject to validation by further research and/or field evaluations using accident data.

Preliminary spacing guidelines were developed through a limited application of HVOSM (see Table 10) and vary with both driveway slope and speed as follows:

- For driveway slopes of 6:1, the minimum driveway spacing varies from 15.3 m to 30.5 m for speeds ranging from 72.5 km/h to 96.6 km/h respectively.
- For driveway slopes of 8:1, the minimum driveway spacing varies from 7.6 m to 22.9 m for speeds ranging from 72.5 km/h to 96.6 km/h respectively.
- For driveway slopes of 10:1, the minimum driveway spacing varies from 0.0 m to 7.6 m for speeds ranging from 72.5 km/h to 96.6 km/h respectively.
- These recommendations are presented in tabular form in Table 10, page 24.
- Further study of the problem should be considered and, if warranted, could include:
    - An expanded HVOSM study (expand the matrix of conditions examined).
    - Evaluation of alternatives, such as underground drainage between multiple driveways and the benefit/cost of the alternatives.
    - Full-scale crash tests.
    - An in-depth review of field experience and special accident studies using national accident databases, such as NASS, CDS, and HSIS.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes.

ACKNOWLEDGMENTS

The authors express their appreciation to Mr. Dale Stein of the Texas Department of Transportation, San Antonio District, and Project Director, for his cooperation and thoughtful advise during the course of the study.

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1. INTRODUCTION

1.1 Background

TxDOT has led the nation in the development and implementation of safety treated drainage structures. These have included sloped culvert ends and pipe grates across the larger culvert openings, which are used on both cross drainage and parallel drainage structures. Also addressed in these studies was the embankment slope needed for ditches and driveways for safe traversable recovery by errant motorists. The same or similar designs and criteria are now used in many states. Although precise figures are not available, it is apparent that their use has greatly enhanced highway safety.

TTI assisted TxDOT in the development of the treatments and the guidelines for their use. Selected reports describing these developments can be found in references 1 through 5.

Development of these guidelines did not include consideration for the hazard that may be created by driveways in close proximity to each other. Current TxDOT policy does not address safety issues at closely spaced driveways in relation to ran-off-the-road accidents. As an example, under current policy, a landowner may be allowed multiple driveway access points from a frontage road to the property, and there are guidelines to determine what the minimum spacing between driveways should be based on access control factors. However, there are no guidelines to determine what the minimum driveway spacing should be when pipes or box culverts are present under the driveways. A significant safety hazard may exist if an errant vehicle leaves the roadway in the vicinity of multiple driveways. The basic concern is that an errant vehicle will engage and traverse one driveway/culvert configuration, become airborne, and then strike the next driveway in such a way as to expose the occupants to significant risks. Examples of closely spaced driveways with safety treated culvert ends are shown in Figure 1. The potential problem is illustrated in Figure 2.

1.2 Objective

The objective of this project was to evaluate the safety aspects of safety-end treatments on parallel drainage structures when used on multiple driveways in close proximity to each other, and then determine acceptable spacing dimensions of multiple driveways for different roadway classes.

1.3 Research Approach

This project was scheduled for two years, with the need for the second year contingent on the first year's results. In the first year an effort was made to address the problem through surveys of TxDOT and other state DOTs to determine their practices and experience with the safety performance of driveways, including closely spaced driveways, and to acquire any available accident information. A review of the literature was also made for any relevant information. Upon completion of these tasks, it became clear that sufficient information was not available from these sources to develop driveway spacing guidelines. A limited study was then made through computer simulation, using the Highway-Vehicle-Object-Simulation-Model (HVOSM), a widely used and

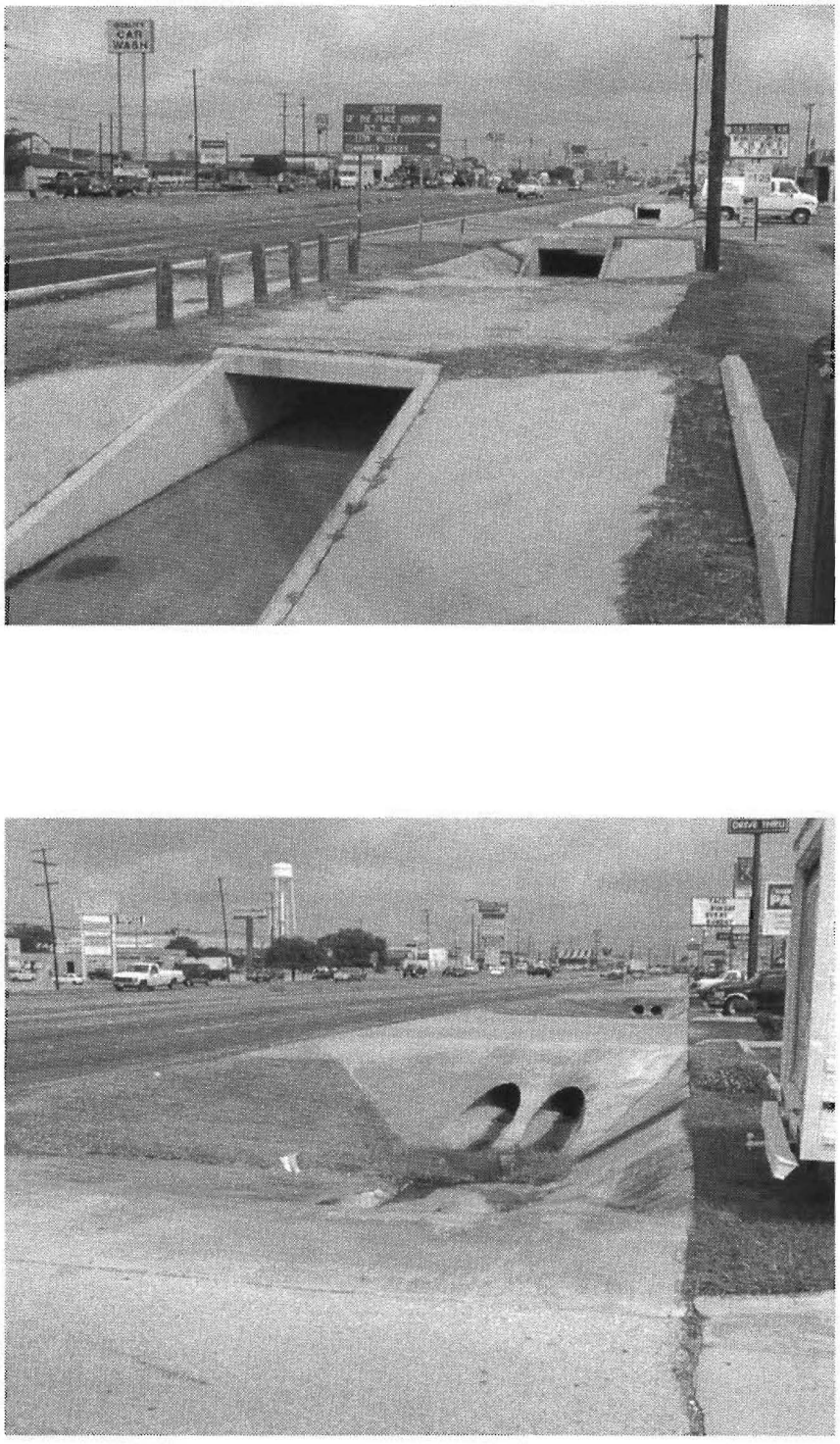


Figure 1. Examples of Closely Spaced Driveways

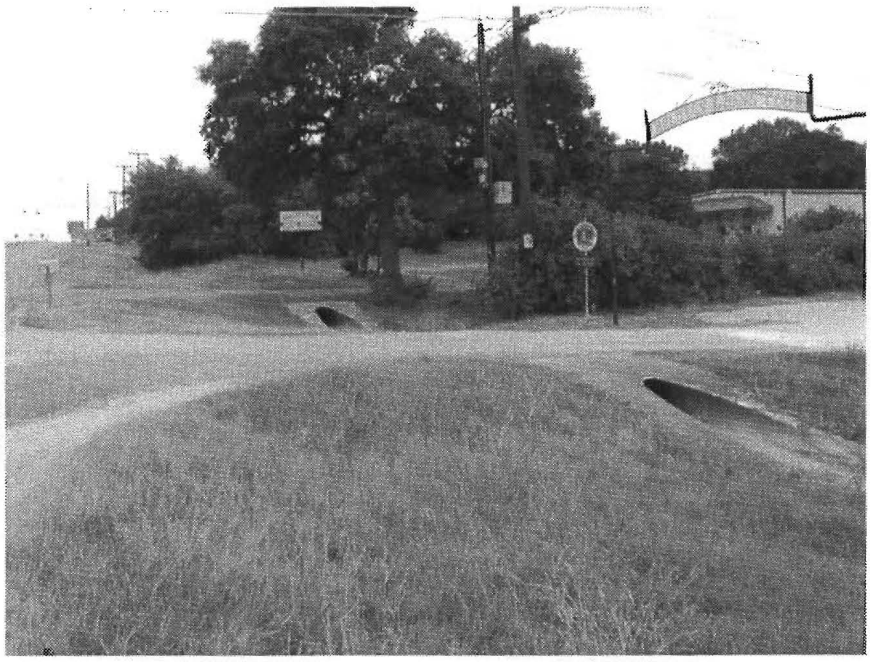
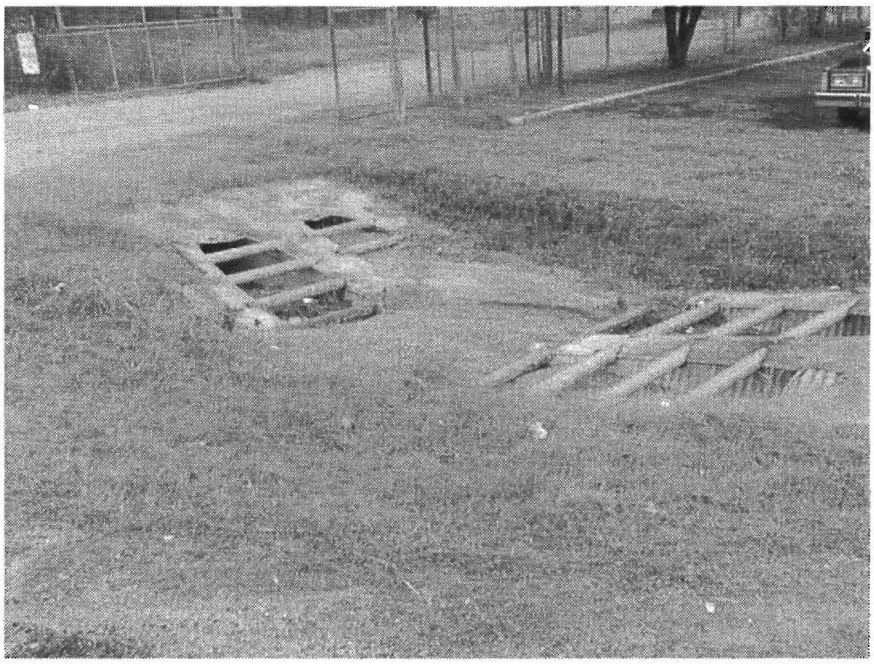


Figure 1. Examples of Closely Spaced Driveways (continued)



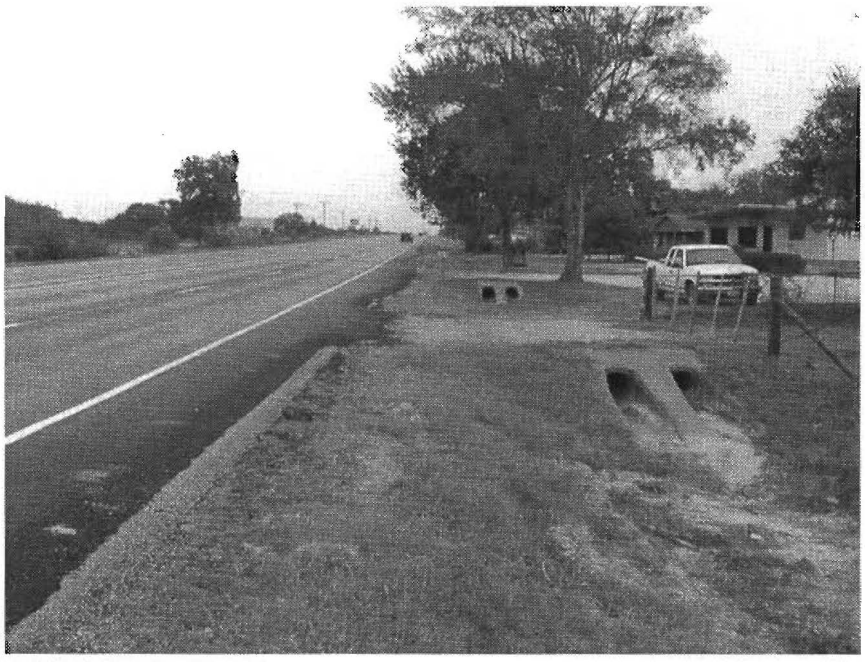


Figure 1. Examples of Closely Spaced Driveways (continued)

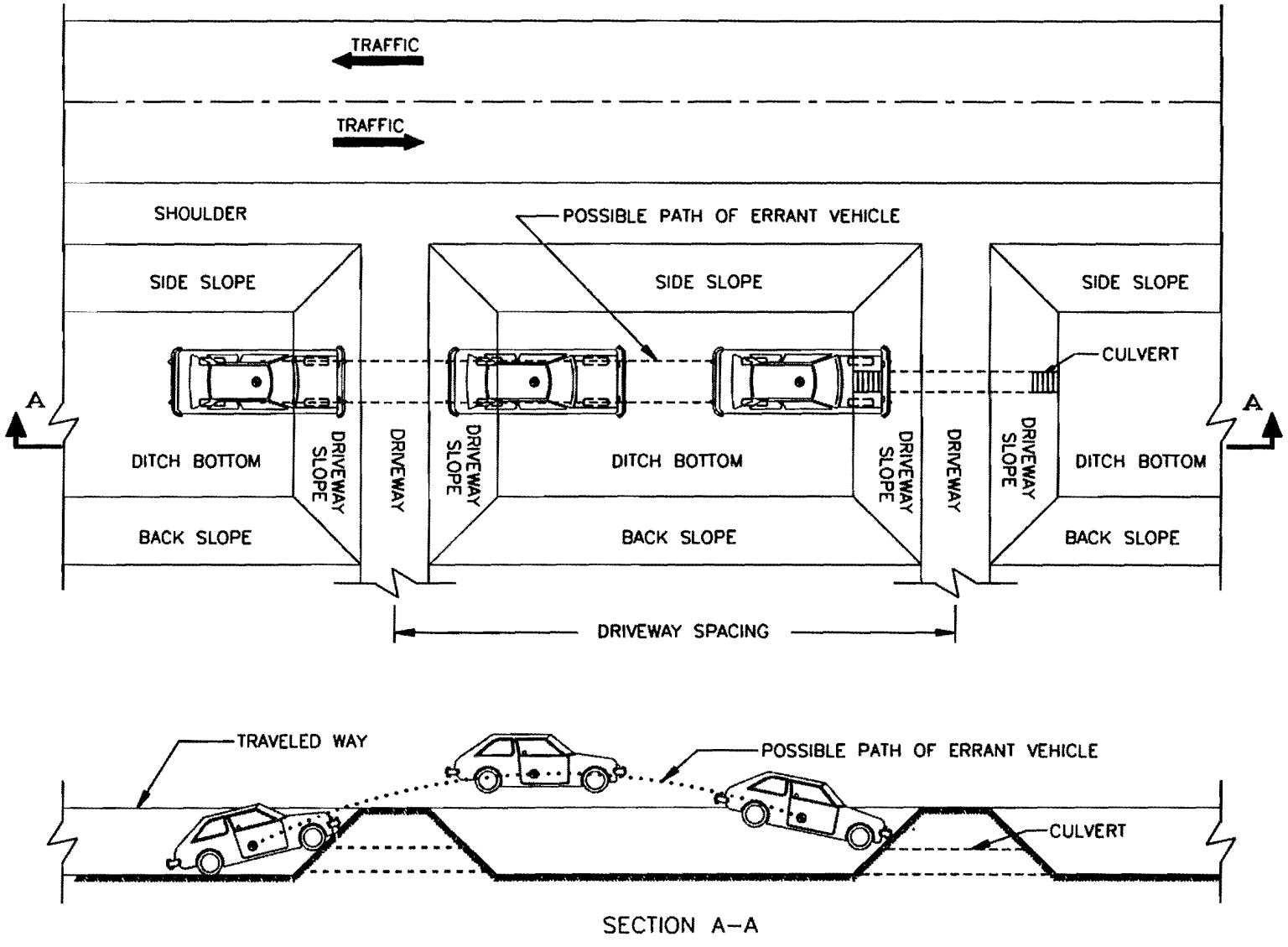


Figure 2. Illustration of Potential Problem

validated program for studying vehicular response to ran-off-the-road incidents involving roadside geometric features (6). Use of HVOSM provided data from which preliminary spacing criteria could be developed. Funding for the second year's work was not approved, and hence more comprehensive guidelines were not developed.

2. A REVIEW OF THE LITERATURE AND SURVEYS OF STATE DOTS

2.1 Literature Review

Location and spacing of driveways has received considerable study in relation to access management and control, especially in urban and suburban settings. Spacing guidelines obtained seek to minimize disruptions and optimize traffic flow on major arterials to which the driveways abut, and seek to improve traffic safety on arterials. Examples of guidelines determined from these studies can be found in references 7 through 14. The TxDOT manual on driveways and their spacing (15) is based in large part on access management and control considerations.

As previously mentioned, TTI has conducted studies to determine recommended design criteria for driveways and end treatments of culverts that traverse driveways (1, 2, 3, 4, 5). These criteria have recommended driveway side slopes and the need for safety grates on sloping culvert end treatments. However, these studies did not address the safety of driveways in close proximity to each other. Examples of the safety treatment of culvert ends under driveways were shown in Figure 1.

An attempt was also made to determine if any studies had been made using accident data to evaluate the safety of driveways in general and for closely spaced driveways in relation to ran-off-the-road accidents. No such data could be found.

2.2 Surveys

Survey letters were sent to each state DOT in the United States, a copy of which is given in Appendix A. A similar letter was sent to each district within TxDOT, a copy of which is given in Appendix B. The survey sought to determine:

a. if the DOT/district had driveway spacing guidelines;
b. if the guidelines were developed considering ran-off-the-road accidents; and
c. if data were available involving ran-off-the-road accidents with driveways, and with closely spaced driveways.

The DOTs were also asked to provide a copy of the policy/guideline used for driveway spacings.

Table 1 summarizes the results of the state DOT survey. All but three of the states indicated that the safety of errant motorists who run off the road were not considered in determining their spacing guidelines. When queried further, it was found that these three states misunderstood the question, and in fact, their spacing guidelines were not based on a consideration of ran-off-the-road accidents, per se, but on conflict analysis and similar evaluations. Two states indicated that they were aware of ran-off-the-road accident problems with driveways, but no documented data were available. Table 2 summarizes the spacing guidelines used by the state DOTs responding to the survey. Note that distances are in meters and speeds are in kilometers per hour.

Table 1. Summary of State DOT Survey

State	Does state have driveway spacing policies?	Was safety of errant motorists who may encounter a driveway a factor in selection of the policies?	Were there any similar studies conducted in the state?	Aware of ran-off-the-road accident problems?
Alabama	N	N	N	N
Arizona	N	N	N	N
Arkansas	N	N	N	N
California	N	N	N	N
Delaware	N	N	N	N
Illinois	N	N	N	N
Indiana	Y	N	N	N
Iowa	Y	Y	N	N
Maine	N	N	N	N
Maryland	Y	N	N	N
Massachusetts	N	N	N	N
Michigan	Y	N	N	N
Minnesota	Y	N	N	N
Mississippi	Y	N	N	N
Missouri	Y	Y	N	N
Nebraska	Y	N	N	N
Nevada	Y	N	N	N
New Hampshire	N	N	N	N
New Mexico	Y	Y	N	Y
New York	Y	N	N	N
North Dakota	Y	N	N	N
North Carolina	Y	N	N	N
Oklahoma	Y	N	N	Y
Pennsylvania	Y	N	N	N
Rhode Island	Y	N	N	N
South Carolina	Y	N	N	N
Tennessee	Y	N	N	N
Utah	Y	N	N	N
Virginia	Y	N	N	N
West Virginia	Y	N	N	N
Wyoming	Y	N	N	N

Table 2. Summary of State DOT Driveway Spacing Guidelines

Note: Speed is in km/h and spacing is in meters.

STATE	SPACING GUIDELINES	
Indiana	**Highway Speed**	**Minimum Spacing**
	48	56
	56	75
	64	92
	72	107
	80	120
	88	133
Iowa	**Highway Type**	**Minimum Spacing**
	Priority I	Allowed only at interchange locations
	Priority II	244
	Priority III	
	Rural designed area	92
	Urban designed area	61
	Priority IV	
	Rural designed area	61
	Urban designed area	31
Maryland	Minimum Spacing : 31	
Michigan	**Speed**	**Minimum Spacing**
	40	39
	48	56
	56	75
	64	92
	72	106
	80 and above	139
Minnesota	**Highway Type**	**Minimum Spacing**
	Residential	
	Urban	13
	Rural	13
	Commercial	
	Urban	17
	Rural	19
Mississippi	Minimum Spacing : 23	
Missouri	Minimum Spacing : 31	

Table 2. Summary of State DOT Driveway Spacing Guidelines (continued)

Note: Speed is in km/h and spacing is in meters.

STATE	SPACING GUIDELINES		
Nebraska	**Highway Type**	**Minimum Spacing**	
	Rural	305	
	Undeveloped Urban	> 305 (No. of access per mile <=3)	
Nevada	Minimum Spacing : 16		
New Mexico	**Highway Type**	**Suggested Minimum Spacing**	**Comment**
	Rural Arterial		Roadway hazards in the recovery zone, such as fixed objects or steep embankments, may need to be removed, reconstructed, or shielded by a proper barrier. In urban areas with posted speeds of 64 km/h or less and vertical curbs, a recovery zone of at least 0.46 m shall be provided.
	Primary	Two driveways per 1.6 km per side	
	Secondary	Six driveways per 1.6 km per side	
	Rural Collector	No Restriction	
	Rural Local	No Restriction	
	Urban Arterial		
	Primary	Only for major traffic generators	
	Secondary	Only one driveway per 61 m of frontage	
	Urban Collector	One driveway per 15 m of frontage	
	Urban Local	No restriction	
New York	Considers traffic conflicts only		
North Carolina	Minimum spacing : 17		
North Dakota	Minimum spacing : 152		
Oklahoma	**Driveway Type**	**Minimum Spacing**	
	Private non-commercial	25	
	Public - low to medium volume	30	
	Public - high volume	35	
	Commercial	35	
	Industrial	40	
Pennsylvania	Minimum spacing : 6		
Rhode Island	Minimum Spacing : 6		

Table 2. Summary of State DOT Driveway Spacing Guidelines (continued)

Note: Speed is in km/h and spacing is in meters.

State	Spacing Guidelines	
South Carolina	**Speed**	**Minimum Spacing**
	48 or less	31
	56	46
	64	61
	72	76
	80	92
	88 and above	107
Tennessee	Minimum spacing : 14	
Utah	**Highway Speed**	**Minimum Spacing**
	40	32
	48	38
	56	46
	72	70
	80	84
Virginia	Minimum spacing : 8	
West Virginia	**Highway Speed**	**Minimum Spacing**
	40	32
	48	38
	56	46
	64	56
	72	70
	80	84
	88	100
Wyoming	Minimum spacing : 8	

Table 3 summarizes the response of the TxDOT districts. All districts use the driveway guidelines given in reference 15. None of the districts indicated an awareness of accident problems with driveways or closely spaced driveways, and none of the districts had any relevant accident data.

Table 3. Summary of TxDOT Survey

District	Does district follow the state spacing guidelines?	Does district have other driveway spacing policies?	Was safety of errant motorists who may encounter a driveway a factor in selection of the guidelines?	Were there any similar studies conducted in the district?	Are they aware of ran-off-the-road accident problems?
Amarillo	Y	N	N	N	N
Atlanta	Y	N	N	N	N
Austin	Y	N	N	N	N
Beaumont	Y	N	N	N	N
Brownwood	Y	N	N	N	N
Bryan	Y	N	N	N	N
Childress	Y	N	N	N	N
Corpus Christi	Y	N	N	N	N
Dallas	Y	N	N	N	N
El Paso	Y	N	N	N	N
Fort Worth	Y	N	N	N	N
Houston	Y	N	N	N	N
Laredo	Y	N	N	N	N
Lubbock	Y	N	N	N	N
Lufkin	Y	N	N	N	N
Odessa	Y	N	N	N	N
Paris	Y	N	N	N	N
San Angelo	Y	N	N	N	N
San Antonio	Y	N	N	N	N
Tyler	Y	N	N	N	N
Waco	Y	N	N	N	N
Wichita Falls	Y	N	N	N	N
Yoakum	Y	N	N	N	N

3. COMPUTER SIMULATIONS

3.1 Selection of Program and Study Parameters

Upon completion of the literature search and the surveys, it became clear that sufficient information was not available from these sources to develop driveway spacing guidelines. A limited study was then made through computer simulation, using the Highway-Vehicle-Object-Simulation-Model (HVOSM), a widely used and validated program for studying vehicular response to ran-off-the-road incidents involving roadside geometric features (6). Examples of the use of HVOSM for this purpose can be found in references 1, 4, 16, and 17. Use of HVOSM provided data from which preliminary spacing criteria could be developed

HVOSM was used to determine the response of vehicles traversing driveways in close proximity to each other. Figure 3 illustrates the driveway parameters examined in the analysis. Note that ditch depth and driveway width were held constant at 0.9 m and 7.6 m, respectively, in all the simulations. Also note that "S" is the driveway spacing, and "X" is the distance beyond the toe of the slope of the first driveway at which the vehicle returns to the ground. The matrix of parameters investigated include the following:

Vehicles: Two (2) - a small car (Honda Civic weighing 880 kg) and a large pickup (3/4-ton Chevrolet pickup weighing 2080 kg). Note that these vehicles are very similar to the design vehicles used in the evaluation of roadside features according to NCHRP Report 350 (18).

Vehicle approach path: One (1) - The vehicle was assumed to approach the driveway in a "down-the-ditch" direction, or perpendicular to the driveway's centerline.

Vehicle speeds: Four (4) - 72.5 km/h (45 mph), 80.5 km/h (50 mph), 88.6 km/h (55 mph), and 96.6 km/h (60 mph).

Driveway slopes: Three (3) - 6:1, 8:1, and 10:1

Driveway spacings: Five (5) - 7.63 m (25 ft), 15.25 m (50 ft), 22.88 m (75 ft), 30.5 m (100 ft), and 38.1 m (125 ft).

Sample input data for each of the two vehicles are given in Appendix C.

3.2 Simulation Results

A total of 120 runs were made to encompass each of the parameter combinations. Results of the runs are summarized in tables 4 through 9. Vehicular stability was the primary criteria used in evaluating the results. Vehicular overturns were judged unacceptable. Also judged unacceptable were those cases where the vehicle was predicted to impact the second driveway as the vehicle

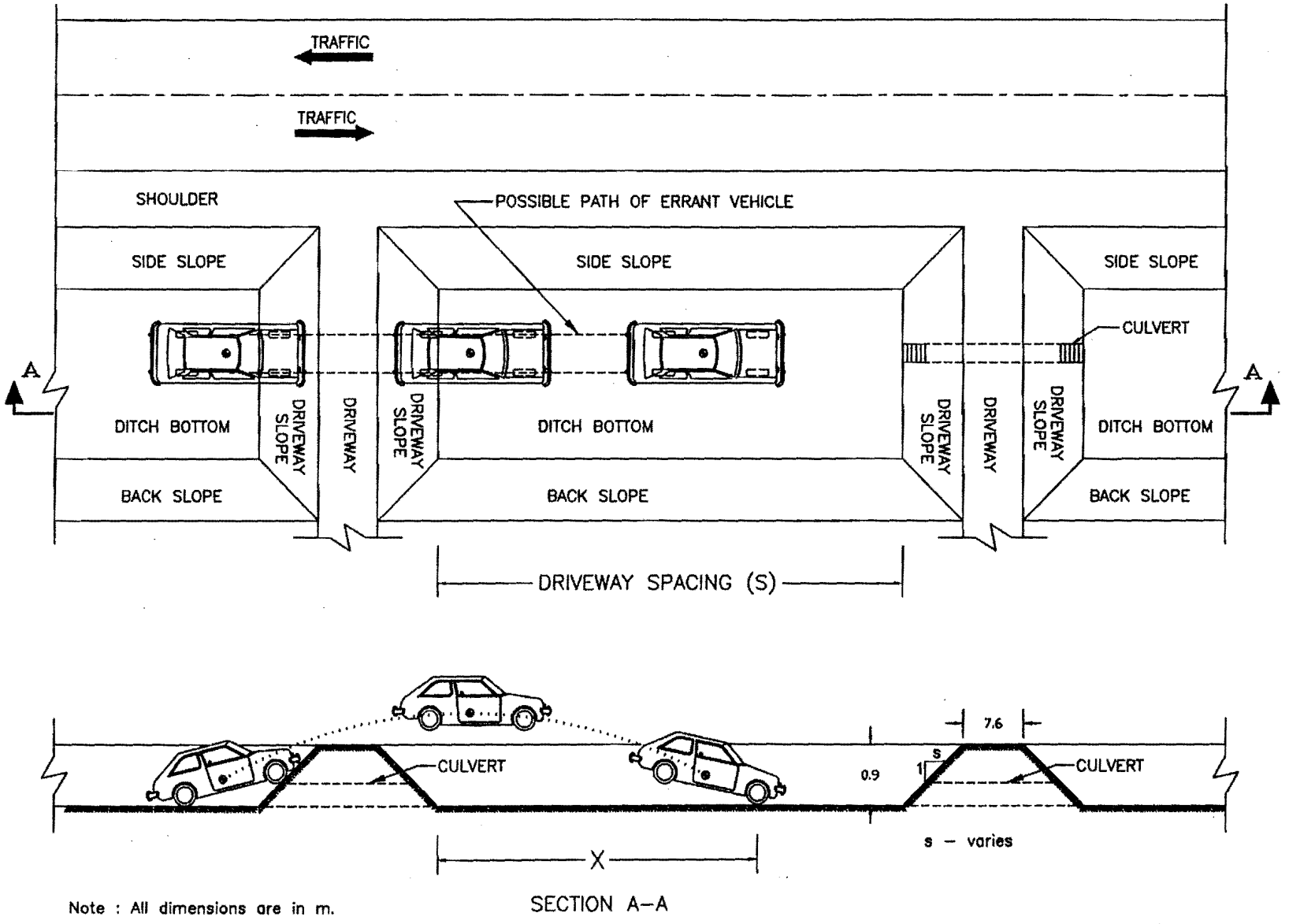


Figure 3. Parameters of HVOSM Study

Table 4. Small Car - Driveway Slope 6:1

DEPARTURE SPEED (km/h)	DRIVEWAY SPACING "S"[a] (m)	DISTANCE "X"[a] (m)	VEHICLE OVERTURN?
72.5	7.6	2.4	No
72.5	15.3	2.4	Yes[b]
72.5	22.9	2.4	No
72.5	30.5	2.4	No
72.5	38.1	2.4	No
80.5	7.6	8.2	Yes
80.5	15.3	8.5	No
80.5	22.9	8.5	Yes[b]
80.5	30.5	8.5	No
80.5	38.1	8.5	No
88.6	7.6	11.3	Yes
88.6	15.3	12.2	No
88.6	22.9	12.2	Yes
88.6	30.5	12.2	Yes
88.6	38.1	12.2	Yes
96.6	7.6	15.3	Yes
96.6	15.3	16.5	Yes
96.6	22.9	17.1	No
96.6	30.5	17.1	Yes
96.6	38.1	17.1	Yes

[a] See Figure 1

[b] Inconclusive result - see discussion in section 3.2

Table 5. Pickup Truck - Driveway Slope 6:1

DEPARTURE SPEED (KPH)	DRIVEWAY SPACING "S"[a] (m)	DISTANCE "X"[a] (m)	VEHICLE OVERTURN?
72.5	7.6	8.4	No
72.5	15.3	8.5	No
72.5	22.9	8.5	Yes[b]
72.5	30.5	8.5	No
72.5	38.1	8.5	Yes[b]
80.5	7.6	12.4	Yes
80.5	15.3	14.6	Yes
80.5	22.9	14.6	No
80.5	30.5	14.6	Yes[b]
80.5	38.1	14.6	No
88.6	7.6	20.1	No
88.6	15.3	19.2	Yes
88.6	22.9	20.1	Yes
88.6	30.5	20.1	No
88.6	38.1	20.1	No
96.6	7.6	27.5	No
96.6	15.3	25.9	No
96.6	22.9	26.8	Yes
96.6	30.5	27.5	Yes
96.6	38.1	27.5	No

[a] See Figure 1

[b] Inconclusive result - see discussion in section 3.2

Table 6. Small Car - Driveway Slope 8:1

DEPARTURE SPEED (km/h)	DRIVEWAY SPACING "S"[a] (m)	DISTANCE "X"[a] (m)	VEHICLE OVERTURN?
72.5	7.6	1.8	Yes[b]
72.5	15.3	1.8	Yes[b]
72.5	22.9	1.8	Yes[b]
72.5	30.5	1.8	No
72.5	38.1	1.8	No
80.5	7.6	4.0	No
80.5	15.3	4.0	No
80.5	22.9	4.0	No
80.5	30.5	4.0	No
80.5	38.1	4.0	No
88.6	7.6	7.9	No
88.6	15.3	8.2	Yes[b]
88.6	22.9	8.2	Yes[b]
88.6	30.5	8.2	Yes[b]
88.6	38.1	8.2	No
96.6	7.6	9.5	No
96.6	15.3	9.5	No
96.6	22.9	9.5	Yes[b]
96.6	30.5	9.5	Yes[b]
96.6	38.1	9.5	Yes[b]

[a] See Figure 1

[b] Inconclusive result - see discussion in section 3.2.

Table 7. Pickup Truck - Driveway Slope 8:1

DEPARTURE SPEED (KPH)	DRIVEWAY SPACING "S"[a] (m)	DISTANCE "X"[a] (m)	VEHICLE OVERTURN?
72.5	7.6	2.4	No
72.5	15.3	2.4	No
72.5	22.9	2.4	No
72.5	30.5	2.4	No
72.5	38.1	2.4	No
80.5	7.6	4.6	No
80.5	15.3	4.6	Yes[b]
80.5	22.9	4.6	No
80.5	30.5	4.6	No
80.5	38.1	4.6	No
88.6	7.6	8.2	No
88.6	15.3	9.2	No
88.6	22.9	9.2	Yes[b]
88.6	30.5	9.2	No
88.6	38.1	9.2	No
96.6	7.6	12.5	No
96.6	15.3	14.9	No
96.6	22.9	14.9	No
96.6	30.5	14.9	Yes[b]
96.6	38.1	14.9	Yes[b]

[a] See Figure 1

[b] Inconclusive result - see discussion in section 3.2.

Table 8. Small Car - Driveway Slope 10:1

DEPARTURE SPEED (km/h)	DRIVEWAY SPACING "S"[a] (m)	DISTANCE "X"[a,c] (m)	VEHICLE OVERTURN?
72.5	7.6	-13.1	No
72.5	15.3	-13.1	No
72.5	22.9	-13.1	No
72.5	30.5	-13.1	No
72.5	38.1	-13.1	No
80.5	7.6	-7.6	No
80.5	15.3	-7.6	No
80.5	22.9	-7.6	No
80.5	30.5	-7.6	No
80.5	38.1	-7.6	No
88.6	7.6	0.8	No
88.6	15.3	0.8	No
88.6	22.9	0.9	No
88.6	30.5	0.8	Yes[b]
88.6	38.1	0.8	No
96.6	7.6	5.1	No
96.6	15.3	5.1	No
96.6	22.9	5.1	No
96.6	30.5	5.1	Yes[b]
96.6	38.1	5.1	No

[a] See Figure 1

[b] Inconclusive result - see discussion in section 3.2.

[c] Negative sign indicates vehicle landed on first driveway before encountering ditch bottom.

Table 9. Pickup Truck - Driveway Slope 10:1

DEPARTURE SPEED (KPH)	DRIVEWAY SPACING "S"[a] (m)	DISTANCE "X"[a,c] (m)	VEHICLE OVERTURN?
72.5	7.6	-12.5	No
72.5	15.3	-12.5	No
72.5	22.9	-12.5	No
72.5	30.5	-12.5	No
72.5	38.1	-12.5	No
80.5	7.6	-6.1	No
80.5	15.3	-6.1	No
80.5	22.9	-6.1	No
80.5	30.5	-6.1	No
80.5	38.1	-6.1	No
88.6	7.6	1.2	No
88.6	15.3	1.2	No
88.6	22.9	1.2	No
88.6	30.5	1.2	No
88.6	38.1	1.2	No
96.6	7.6	5.2	No
96.6	15.3	5.2	Yes[b]
96.6	22.9	5.2	No
96.6	30.5	5.2	No
96.6	38.1	5.2	No

[a] See Figure 1

[b] Inconclusive result - see discussion in section 3.2.

[c] Negative sign indicates vehicle landed on first driveway before encountering ditch bottom.

returned to the ground after being launched by the first driveway. In some cases, the program predicted overturn after the vehicle had returned to the ground upright and then encountered the second driveway. However, upon closer examination, it became apparent in these cases that the predicted response beyond the initial return to the ground was suspect. Heavy loads on the vehicle's suspension that would have otherwise caused suspension failures are not properly accounted for in HVOSM.

Computer runs were also made to simulate a "baseline condition" which was encroachment on a single driveway, having a 6:1 slope, for each combination of vehicles and vehicle speeds. Results of these runs indicated that the pickup truck could traverse the 6:1 slope at each of the four impact speeds without overturning. Results of these runs for the small car indicated overturn for impact speeds greater that 80.5 km/h (50 mph).

3.3 Tentative Guidelines Based on Simulation Results

Shown in Table 10 are tentative guidelines based on an analysis of the previously described HVOSM runs. Two basic criteria were used in determining the "minimum spacing indicated" values shown in the table:

(1) Upon traversing the first driveway, the vehicle will return to the ditch bottom before encountering the next driveway, and
(2) the vehicle will not overturn as a result of initial ground contact after traversing the first driveway.

As noted in Tables 4 through 9, and as discussed in section 3.2, in some cases the vehicle returned to the ground in an upright position after traversing the first driveway and then overturned upon contact with the second driveway. Such a response must be viewed as inconclusive due to HVOSM limitations.

Table 10. Tentative Spacing Guidelines for Multiple Driveways

Driveway Slope	Speed (km/h)	Minimum Spacing Indicated (m)
6.1	72.5	15.3
	80.5	22.9
	88.6	30.5
	96.6	30.5
8:1	72.5	7.6
	80.5	7.6
	88.6	15.3
	96.6	22.9
10:1	72.5	0
	80.5	0
	88.6	7.6
	96.6	7.6

4. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

TxDOT and other DOTs have made significant improvements in the safety of driveways for errant motorists who leave the travelway. Relatively flat slopes and sloped culvert ends with grates enable a vehicle to traverse a driveway that abuts the travelway without coming to an abrupt and deadly stop. However, depending on the speed, the vehicle may become airborne for some distance after traversing the driveway. Desirably, there will be a safe recovery area downstream from the driveway—one that is free of hazardous objects or features.

Driveways in close proximity to each other may pose a hazard to an errant motorist. This is a concern if, after traversing one driveway, a vehicle becomes airborne and then strikes a second driveway upon its return to the ground. The purpose of this study was to develop guidelines for minimum spacing between driveways in consideration of safety for ran-off-the-road incidents.

This study was intended to be a two-year study, with the effort in the first year concentrating on a summary of existing practices and accident experience throughout Texas and the other state DOTs. Work in the second year was to fill voids in the data found in the first year's work. Very little substantive data was found through surveys of state practices and through accident data. A limited computer simulation study was conducted with the Highway-Vehicle-Object-Simulation-Model (HVOSM) to gain insight into vehicular behavior upon crossing a driveway. Use of HVOSM provided data from which preliminary spacing criteria could be developed. These tentative guidelines are given in Table 10 of this report.

Funding for the second year's work was not approved, and hence more comprehensive guidelines were not developed. Nonetheless, TxDOT may wish to incorporate the preliminary findings on a limited, experimental basis, subject to validation by further research and/or field evaluations using accident data.

Conclusions and recommendations are:

- Most DOTs (TxDOT included) have minimum driveway spacing requirements, but they are not based on consideration of ran-off-the-road accidents.
- The DOTs are not aware of ran-off-the-road accident problems associated with closely spaced driveways.
- Accident data limitations may preclude an accurate determination of the extent of any problems that may exist.
- Accident severity at multiple driveway locations will, in many cases, be influenced by factors other than the driveways, such as trees, poles, and other objects in or along the right-of-way.
- The HVOSM computer program can be used to study the dynamic behavior of vehicles for multiple driveway conditions.
- Preliminary spacing guidelines were developed through a limited application of HVOSM (see Table 10).

- Further study of the problem should be considered and, if warranted, could include:
  - An expanded HVOSM study (expand the matrix of conditions examined).
  - Evaluation of alternatives, such as underground drainage between multiple driveways and the benefit/cost of the alternatives.
  - Full-scale crash tests.
  - An in-depth review of field experience and special accident studies using national accident databases, such as NASS, CDS, and HSIS.

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APPENDIX A

SURVEY LETTER TO STATE DOTS

February 28, 1997

Mr. John Doe
Design Engineer
XYZ DOT

Re: Safety at Driveways

Dear Mr. Doe:

The Texas Transportation Institute is conducting a study for the Texas Department of Transportation (TxDOT) to examine safety issues related to multiple driveways in close proximity to each other. TxDOT has guidelines and policies that define minimum distances between driveways, dependent on roadway type and other factors. Where applicable, spacing criteria are typically based on access control factors and the need to minimize congestion on the primary roadway to which the driveways abut.

Of concern in the present study is the safety of an errant motorist who, upon leaving the travelway, encounters and traverses a driveway. In many cases the vehicle will become airborne upon traversing a driveway. Occupant safety in such cases is dependent, among other factors, on terrain conditions at the point the vehicle returns to the ground. A second driveway may create an increased risk if in reasonably close proximity to the driveway traversed. Please see illustrations on the attached figure.

Enclosed is a short survey seeking information relative to driveway spacing criteria and safety associated with ran-off-the-road accidents involving driveways. Any data you can provide will greatly assist us in this study, including any comments you may have relative to the study. A stamped, self-addressed envelop is enclosed for returning the survey.

Please call me at (409) 845-4368, or King Mak at (210) 698-2068 if there are any questions.

Thank you.

Sincerely,

Hayes E. Ross, Jr., P.E.
Head, Structural Systems Division

Attachment
Enclosure

SURVEY OF DRIVEWAY SPACING

Note: Information requested herein pertains to roadways or roadway types with design speeds of 50 mph or greater.

1. Does your state have driveway spacing guidelines/policies? _ Y _ N

   Note: If answer to 1 is yes, it would be appreciated if you would send a copy of guidelines/policies to the address shown on the return envelope.

2. If answer to 1 is yes, was safety of errant motorist who may encounter a driveway a factor in selection of the guidelines/policies? _ Y _ N

   Note: If answer to 2 is yes, it would be appreciated if you would send details describing how safety was considered.

3. Have any studies been conducted in your state relative to ran-off-the-road accidents involving driveways? _ Y _ N

   Note: If answer to 3 is yes, it would be appreciated if you would send results of studies to the address shown on the return envelope.

4. Are you aware of any ran-off-the-road accident problems related to driveways in close proximity to each other? _ Y _ N

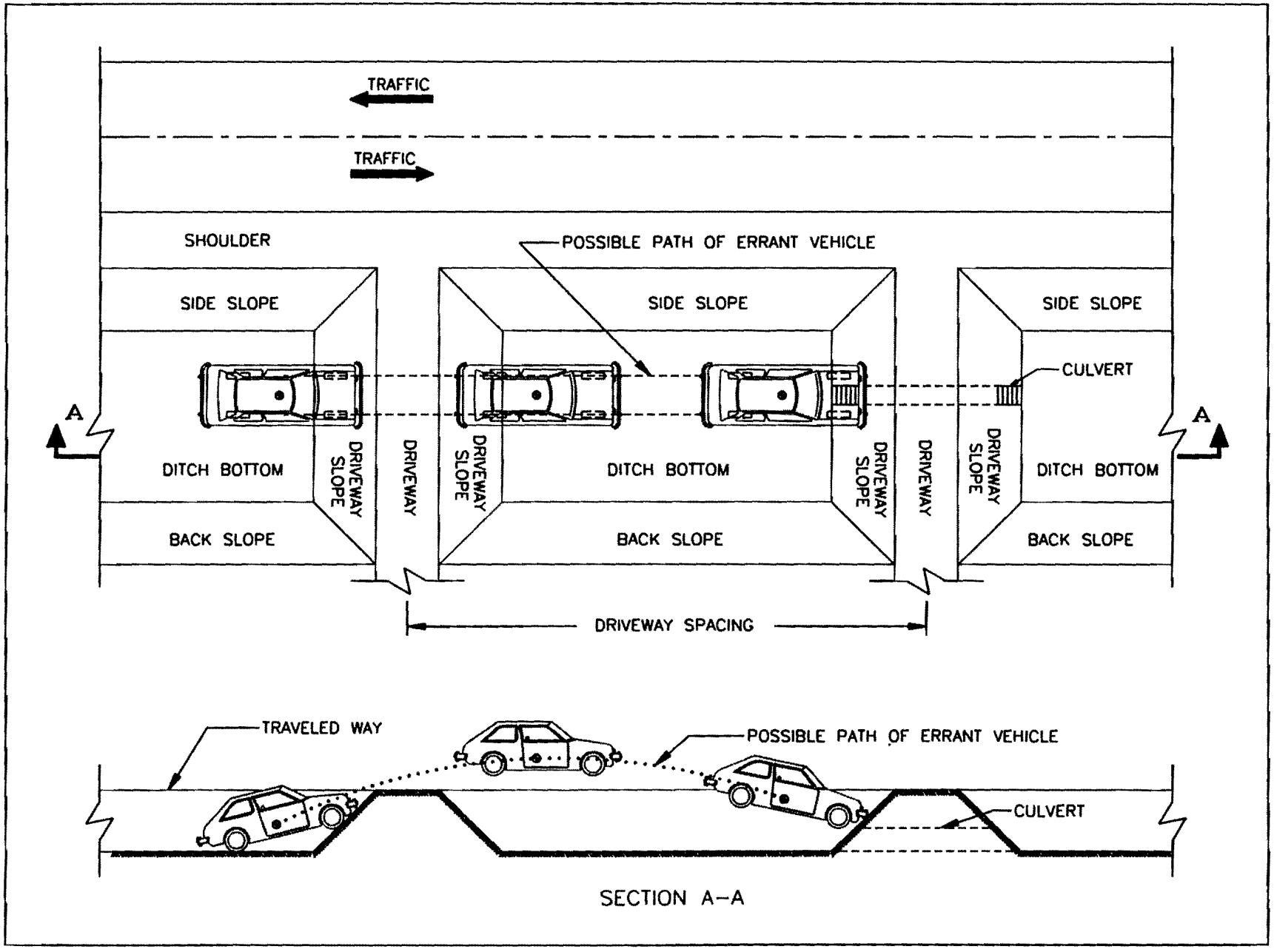
   Note: If answer to 4 is yes, it would be appreciated if you would send this information to the address shown on the return envelope.

The response to this survey was prepared by:

Name: _____
Title: _____
Address: _____
_____
_____
_____

Phone: _____
Fax: _____
e-mail: _____

Please return survey in enclosed envelope.
Thank you.


TRAFFIC
TRAFFIC
SHOULDER
POSSIBLE PATH OF ERRANT VEHICLE
SIDE SLOPE
SIDE SLOPE
SIDE SLOPE
CULVERT
A
A
DITCH BOTTOM
DRIVEWAY SLOPE
DRIVEWAY
DRIVEWAY SLOPE
DITCH BOTTOM
DRIVEWAY SLOPE
DRIVEWAY
DRIVEWAY SLOPE
DITCH BOTTOM
BACK SLOPE
BACK SLOPE
BACK SLOPE
DRIVEWAY SPACING
TRAVELED WAY
POSSIBLE PATH OF ERRANT VEHICLE
CULVERT
SECTION A–A

APPENDIX B

SURVEY LETTER TO TxDOT DISTRICTS

March 28, 1997

Mr. John Doe
Design Engineer
District XYZ
TxDOT

Re: SPR Project 7-2946, "Safety at Driveways"

Dear Mr. Doe:

The Texas Transportation Institute is conducting a study for the Texas Department of Transportation (TxDOT) under the referenced SPR project to examine safety issues related to multiple driveways in close proximity to each other. TxDOT has guidelines and policies that define minimum distances between driveways, dependent on roadway type and other factors, as delineated in the "Title of Manual". Where applicable, spacing criteria are typically based on access control factors and the need to minimize congestion on the primary roadway to which the driveways abut.

Of concern in the present study is the safety of an errant motorist who, upon leaving the travelway, encounters and traverses a driveway. In many cases the vehicle will become airborne upon traversing a driveway. Occupant safety in such cases is dependent, among other factors, on terrain conditions at the point the vehicle returns to the ground. A second driveway may create an increased risk if in reasonably close proximity to the driveway traversed. Please see illustrations on the attached figure.

Enclosed is a short survey seeking information relative to driveway spacing criteria and safety associated with ran-off-the-road accidents involving driveways. Any data you can provide will greatly assist us in this study, including any comments you may have relative to the study. A stamped, self-addressed envelop is enclosed for returning the survey.

Please call me at (409) 845-4368, or King Mak at (210) 698-2068 if there are any questions. Thank you.

Sincerely,

Hayes E. Ross, Jr., P.E.
Head, Structural Systems Division

Enclosure

SURVEY OF DRIVEWAY SPACING

Note: Information requested herein pertains to roadways or roadway types with design speeds of 50 mph or greater.

1. Do you follow the state driveway spacing guidelines/policies? _ Y _ N

2. If answer to 1 is no, do you have different guidelines/policies for the district? _ Y _ N

   Note: If answer to 2 is yes, it would be appreciated if you would send a copy of guidelines/policies to the address shown on the return envelope.

3. If answer to 2 is yes, was safety of errant motorist who may encounter a driveway a factor in selection of the guidelines/policies? _ Y _ N

   Note: If answer to 2 is yes, it would be appreciated if you would send details describing how safety was considered.

4. Have any studies been conducted in your district relative to ran-off-the-road accidents involving driveways? _ Y _ N

   Note: If answer to 4 is yes, it would be appreciated if you would send results of studies to the address shown on the return envelope.

5. Are you aware of any ran-off-the-road accident problems related to driveways in close proximity to each other in your district? _ Y _ N

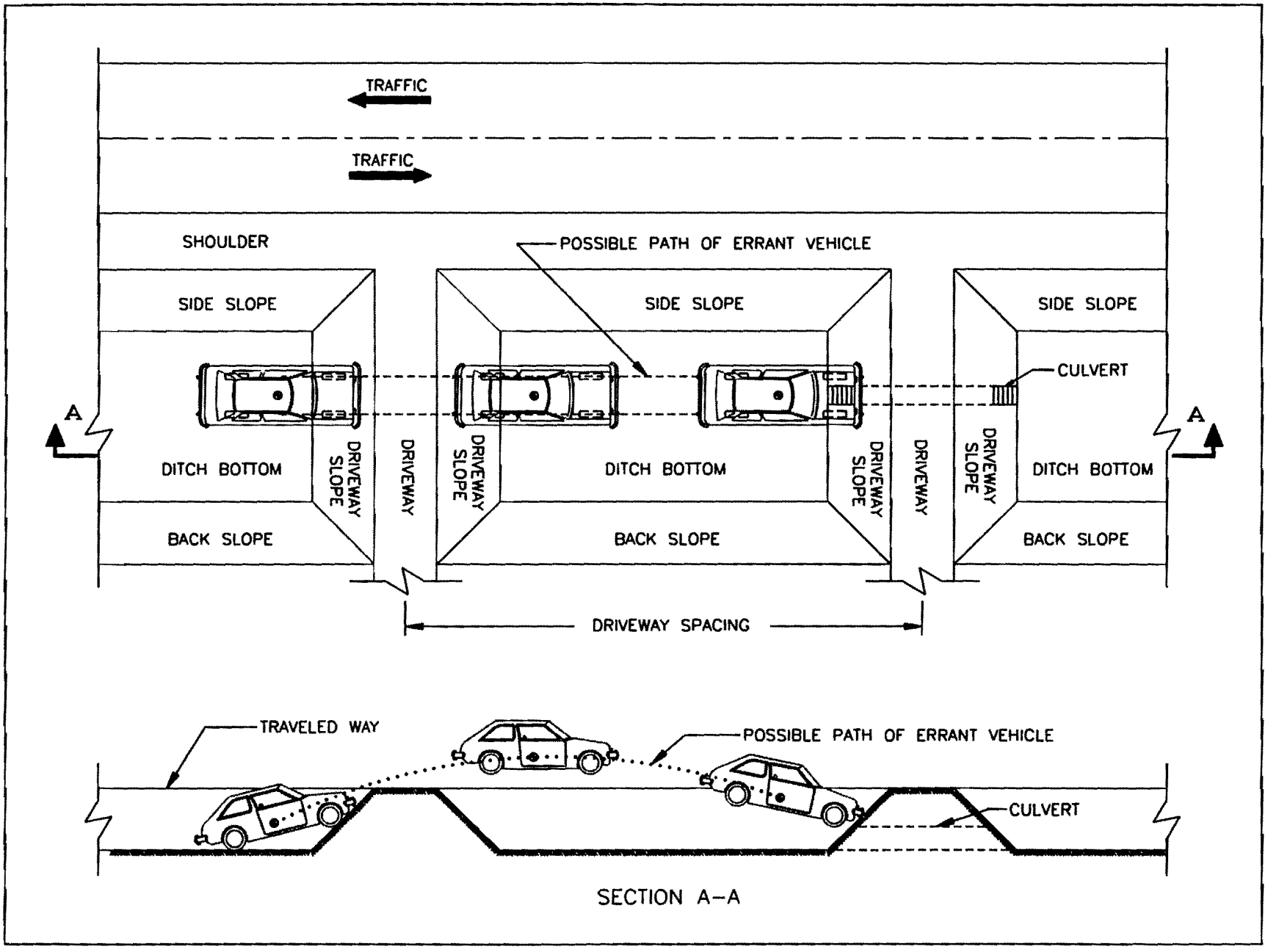
   Note: If answer to 5 is yes, it would be appreciated if you would identify the locations (preferably by control, section, and milepoint) where you have the accident problems and send this information to the address shown on the return envelope.

The response to this survey was prepared by:

Name: _____
Title: _____
Address: _____
_____
_____
_____

Phone: _____
Fax: _____
e-mail: _____

Please return survey in enclosed envelope. Thank you.


TRAFFIC
TRAFFIC
SHOULDER
POSSIBLE PATH OF ERRANT VEHICLE
SIDE SLOPE
SIDE SLOPE
SIDE SLOPE
CULVERT
A
A
DITCH BOTTOM
DRIVEWAY SLOPE
DRIVEWAY
DRIVEWAY SLOPE
DITCH BOTTOM
DRIVEWAY SLOPE
DRIVEWAY
DRIVEWAY SLOPE
DITCH BOTTOM
BACK SLOPE
BACK SLOPE
BACK SLOPE
DRIVEWAY SPACING
TRAVELED WAY
POSSIBLE PATH OF ERRANT VEHICLE
CULVERT
SECTION A–A

APPENDIX C

HVOSM SAMPLE INPUT

```
   Chevy       Run-off-the Road, 45mph
   Side slope - 3:1, 3 feet deep ditch, spacing : 125ft
0.00     14.00    0.001    1.0      0.005    70.0     0.0      0.0      -1.0            1
1.0                                                                                    2
10.123   0.755    0.972    386.4    5155.0   39830.0  39257.0  0.0      1056.58         3
58.195   73.305   65.55    65.94    12.95    12.95    0.00     15.94    3756.0          4
102.55   .60               5.51     38.0     0.001    95221.0                          5
148.08   .70               5.0      48.0     0.001    0.0      45.0     0.000           6
1989.91  7.63     6.0      6.58     7713.72  1.081    0.5      1.00     17317.0         7
0.00     -0.04    0.00     0.0      0.00     0.00     0.0      0.00                     8
300.0    720.0    7.69     792.0    0.000    0.000                                     9
0.0      0.0      0.0      0.0      0.0      0.0      0.0       0.0                    10
0.0000   0.0      0.00     0.0      0.0      0.0                                      11
-3.0     3.0      1.0                                                                 12
-1.8   -1.3   -0.95 -0.55 -0.3   -0.3   -0.4
0.0      6.0      0.5      1.0      1.0      1.0                                      13
10.0     4.0      0.0                                                                 14
  1 0.0    0.0      0.0    25.0    0.00    43.0     3.0    100.0    3.0
  2 120.0  0.0      0.0    25.0    0.00    43.0     3.0    100.0    3.0
  3 138.0  0.0      0.0    25.0    0.00    25.0     0.0    100.0    0.0
  4 163.0  0.0      0.0    25.0    0.00    25.0     0.0    100.0    0.0
  5 181.0  0.0      0.0    25.0    0.00    43.0     3.0    100.0    3.0
  6 306.0  0.0      0.0    25.0    0.00    43.0     3.0    100.0    3.0
  7 324.0  0.0      0.0    25.0    0.00    43.0     0.0    100.0    0.0
  8 349.0  0.0      0.0    25.0    0.00    43.0     0.0    100.0    0.0
  9 367.0  0.0      0.0    25.0    0.00    25.0     3.0    100.0    3.0
 10 2000.  0.0      0.0    25.0    0.00    25.0     3.0    100.0    3.0
750.0    1200.    0.35     5000.0   0.005    1.50                                     17
8.       4000.    0.001    0.25                                                       23
90.09 38.72 12.16 90.09 0.0   12.16 90.09 -38.7212.16 90.09 38.72 2.17
90.09 0.0   2.17  90.09 -38.722.17  -126.538.72 12.16 -126.5-38.7212.16
141.8    220.0    -2.25    254.0    147.5    1.67                                     26
131.0    7.5      -1.7     131.0    7.5      5.75                                     27
                                                                                    9999
```

NONE
FINI

```
   Honda Civic Run-off-the Road, 45mph
   Side slope - 3:1, 3 feet deep ditch, spacing:  25 ft
0.00     14.00    0.001    1.0      0.005    70.0     0.0      0.0      -1.0                    1
1.0                                                                                            2
4.28     0.462    0.356    386.4    1777.0   7292.0   6007.0   1500.0   108.0                   3
37.68    48.92    51.0     51.0     13.26    12.78    0.00     10.875   1421.44                 4
133.0    .75              3.47     31.0     0.001    11700.0                                   5
115.4    .71              2.68     32.5     0.001    30900.0  36.0     0.000                   6
800.0    4.625    15.0     5.67     2409.7   1.197    .5       1.00     -7459.03                7
0.0      0.220    0.0      0.0      0.00     0.00     0.0      0.00                             8
250.0    720.0    12.7     792.0    0.000    0.000                                             9
0.0      0.0      0.0      0.0      0.0      0.0      0.0       0.0                            10
0.0      0.0      0.0      0.0      0.0      0.0                                              11
-3.0     3.0      0.5                                                                        12
-1.5  -1.375-1.25 -1.125-1.0  -0.625-0.3750.0    0.625 1.00  1.45  1.75  2.125
0.0      6.0      0.5      1.0      1.0      1.0                                              13
10.0     4.0      0.0                                                                        14
  1 0.0    0.0      0.0    25.0    0.00    43.0     3.0    100.0    3.0
  2 120.0 0.0       0.0    25.0    0.00    43.0     3.0    100.0    3.0
  3 138.0 0.0       0.0    25.0    0.00    25.0     0.0    100.0    0.0
  4 163.0 0.0       0.0    25.0    0.00    25.0     0.0    100.0    0.0
  5 181.0 0.0       0.0    25.0    0.00    43.0     3.0    100.0    3.0
  6 206.0 0.0       0.0    25.0    0.00    43.0     3.0    100.0    3.0
  7 224.0 0.0       0.0    25.0    0.00    43.0     0.0    100.0    0.0
  8 249.0 0.0       0.0    25.0    0.00    43.0     0.0    100.0    0.0
  9 267.0 0.0       0.0    25.0    0.00    25.0     3.0    100.0    3.0
 10 2000. 0.0       0.0    25.0    0.00    25.0     3.0    100.0    3.0
325.0    240.0    0.40     5000.0   0.075    1.10                                             17
8.       4000.    0.001    0.25                                                              23
66.93 30.0  5.68  66.93 -30.0 5.68  59.80 29.65 15.57 59.80 -29.6515.57
59.18 18.50 15.78 59.18 -18.5015.78 -72.2229.65 15.57 -72.22-29.6515.57
278.9    238.08   -2.05    278.9    10.0     2.85                                             26
70.0     203.57   -2.25    70.0     10.0     2.55                                             27
                                                                                           9999
```

NONE
FINI